



Voluntary starvation onboard a sailboat crossing the Atlantic

Medical Report for Equites Team - Columbusquest

I had the privilege of joining the Equites team, a group of three men (Goltis, Constantin and Andriy) in sailing across the Atlantic. While sailing across the Atlantic is nothing new, this was a different voyage. The team was on a quest - The first part of the voyage they would dry fast. This would last for 7 days until we reach Las Palmas in the Canary Islands. From here onwards they would only drink water until they reach land on the other side of the Atlantic. This changed the sailing expedition into a quest for survival. Constantin and Andriy spend the first 7 days (Palos de la Frontera to Las Palmas) and Goltis a staggering 14 days without any food or water. The combination of calorie deprivation, dehydration and life onboard a small sailboat is an unique and severe stress. The physiological adaptations which occurs under these circumstances are complex. I had limited monitoring equipment available and was able to check on their blood glucose levels, blood pressure, urine dipsticks, pulse but had to rely on clinical evaluation to assess their general condition. Upon reaching land in Las Palmas, Grand Canary Islands I was able to do some blood work and weigh the three men. Marked loss of lean tissue and total body mass are unavoidable and their ultimate survival depended on numerous things. This article reviews some of the physiological and pathologic changes which occurs during total calorie depravation and reviews the factors which may have had an impact on the Equites team's ability to survive.

The First 7 days from Palos de la Frontera to Las Palmas (Constantin and Andriy)

The level of dehydration amongst the team was severely distressing to me as a physician. The physical condition of the team rapidly deteriorated after the first 48 hours. We battled rough seas and sleep was poor for all of us. Towards the end of the first 7 days Constantin quickly became clinically dehydrated with sunken in eyes and decreased skin turgor, Andriy was also clinically dehydrated with reduced peripheral circulation. They both had reduced blood glucose levels, ketonuria and proteinuria.

Constantin lost a total of 5,7 kg which represents a total of 7,5% of his total body weight after the first 7 days. His lowest recorded blood glucose level was 3 mmol/L (54 mg/dL) and his lowest blood pressure levels was 89 systolic over 64 diastolic. His Urea (86 mg/dL) and Creatinine (1,38 mg/dL) levels were raised upon arrival in Las Palmas and normalised 2 days after he started drinking water. He had a raised uric acid level of 10,5 mg/dL which dropped to 6,9 mg/dL upon rehydration. Constantin reported a great improvement in his physical well being after he started drinking water.

Andriy lost a total of 9,2 kg during the first 7 days which represented 11% of his total body weight. His lowest recorded blood glucose levels during this stage was 3,8 mmol/L (68 mg/dL) and his lowest recorded blood pressure was 100 systolic over 74 diastolic . His Urea (74 mg/dL) and Creatinine (1,25 mg/dL) levels were slightly elevated upon arrival in Las Palmas and then normalised after he started drinking water. His kidney functions remained within the normal levels during this time. He had a raised uric acid level of 10,5 mg/dL which reduced to 8.6 mg/dL upon rehydration. Andriy's peripheral

circulation recovered in a dramatic way when he started drinking water. His hands quickly changed from a blotchy blue color to a warm pink. There was no reported loss in his grip strength as he quickly beat me in arm wrestling on the beach.

14 Days survival without food or water (Goltis)

Goltis is a complete different story. He persevered in his dry fasting for another 7 days after we reached Las Palmas. This made the total time period for surviving without food and water 14 days. This has not yet been recorded in medical history before. Goltis was not under 24 hour observation, but from the way that his physical condition deteriorated I can only state what I have seen and in my opinion this fact is true. I have witnessed a man starving himself to the edge of death. Goltis has easily aged himself 20 years in the 2 weeks he spent without food and water. In the end he was sleeping and moving like an old man. He was clinically severely dehydrated and in a very poor physical condition and nothing that said made him change his mind. I am thankful that he survived this period as I was very concerned as it could easily have ended in a different way for him. I was unable to perform any special investigations on him as we left Las Palmas and were at sea after the first 10 days. During the first 14 days his lowest recorded blood glucose level was 4,5 mmol/L (81 mg/dL) and lowest recorded blood pressure was 103 systolic over 73 diastolic. Upon arrival in Las Palmas his Creatine level was slightly elevated at 1.21 mg/dL and his Uric acid level was also raised at 9,3 mg/dL. Two days later this deteriorated to a Urea level of 61 mg/dL, Creatine level of 1,5 mg/dL. His Uric acid level remained more or less stable. As mentioned I was unable to perform any further test on Goltis, but I am sure that his kidney functions would have showed a rapid decline from here onwards. He had persistent ketonuria and proteinuria and was very fatigued and suffered from severe insomnia. Goltis lost a total of 11 kg during the first 7 days which represents 12,6% of his total body weight. It was remarkable and at the same time distressing to be a witness to his mental strength in persevering in his goal - pushing himself to the edge of life.

Energy deprivation

The sudden deprivation of energy and calorie intake sets in motion a sequence of complex physiological responses which aims to increase the possibility to survive. An average man between the age of 20 and 40 weighing 80 kg has an average daily expenditure of 2 700 - 3000 kCal per day. The calorie expenditure is directly related to physical activity. The Equites team did not actively participate in sailing activities so they had a reasonably low energy expenditure. They were however exposed to extreme weather conditions, constant motion of the ship, cabin fever and insomnia.

In the normal fed state, daily energy requirements are met by a combination of carbohydrates and deaminated amino acids. These amino acids are typically derived from a readily available "labile protein" reservoir that is in constant turnover with the free amino acid pool. This protein reservoir correlates to about 1 - 2 kg of lean tissue. Additionally there is about 300g of glycogen available for use (100g in hepatic stores, 200g in muscle and 20g in circulating blood). This corresponds roughly with 1 200 kCal

available for energy in an 24 hour period. In a 70 kg adult this body protein constitutes about 12kg. Combined with the daily obligatory loss of about 20 - 30g of protein this lean tissue would ultimately yield only about two weeks of calories during starvation. Fat stores ultimately provides the most important fuel source during starvation (60 - 70 days worth). The body's main goal during starvation is to utilize these fat stores as the primary fuel while sparing the vital protein stores. Survival therefore does correlate with fat depletion. Weight or protein loss in excess of 40 - 50% is incompatible with life.

During the initial stages of starvation the carbohydrate stores are rapidly depleted. Since the brain relies almost exclusively on glucose for fuel, the easily mobilizable protein stores are quickly utilized for gluconeogenesis. These changes parallel the marked fall in insulin levels seen during early starvation. This early rapid protein loss would prove fatal if metabolic adaptations does not occur. All the members of the Equites team suffered severe hypoglycemic episodes.

Lowest recorded blood glucose values:

Goltis: 3.1 mmol/L (56 mg/dL)

Constantin: 2,8 mmol/L (50 mg/dL)

Andriy: 2,8 mmol/L (50 mg/dL)

Coincident with the fall in insulin levels, increased plasma catecholamines, glucagon and growth hormone stimulate lipase activity. As free fatty acids becomes available acetoacetate, hydroxybutyrate and acetone accumulate (These ketones rise rapidly for 7 - 10 days and continue to do so more gradually over the next few weeks. This change from carbohydrate to fat metabolism would be analogous with a marathon runner "hitting the wall" as a noticeable performance decrement occurs. To further conserve carbohydrate brain glucose consumption falls up to 50% as ketone bodies become available as fuel. It is important to note that protein catabolism and ketone excretion increase significantly in colder weather.

First recorded ketonuria:

Goltis: 48 hours

Constantin: 48 hours

Andriy: 48 hours

As the body adapts to reduce the breakdown of lean body mass, fat and fat fuels gradually replace glucose as main energy source. During the second week of starvation the free fatty acids are less completely metabolized and the resultant ketones permits less use of glucose and decreased muscle catabolism. The body's energy requirements also decreases as the body weight decreases. Most importantly the energy requirements per unit of body weight decreases. This decreased energy expenditure reflects decreased energy utilization for the sodium - potassium pump, protein turnover, temperature regulation and inflammatory immune response. It is important to note that the ketosis of starvation is a physiological response and not lead to the condition seen in pathological states as diabetic keto-acidosis.

Cholesterol levels recorded after 7 days of fasting:Goltis:

Total Cholesterol: 159 mg/dL (Normal range 140 - 240mg/dL)

Triglycerides: 103 mg/dL (Normal range 50 - 130 mg/dL)

Constantin:

Total Cholesterol: Too low to measure

Triglycerides: 119 mg/dL (Normal range 50 - 130 mg/dL)

Andriy:

Total Cholesterol: 284 mg/dL (Normal range 140 - 240mg/dL)

Triglycerides: 153 mg/dL (Normal range 50 - 130 mg/dL)

Widespread physiological changes takes place, both acutely and chronically. Within 48 hours of the onset of starvation, thermoregulatory responses to cooling are decreased and there is an inhibition of sympathetic nervous system activities as manifested in decreased blood pressure and an impairment of peripheral vasoconstriction. Towards the end of the voyage we spent some nights exposed to cold weather on a beach. I could see that the whole team suffered severely due to their reduced body fat and therefore heat retention.

During the next 7 - 14 days a depression of hypoxic ventilatory drive, cardiac output and both systolic and diastolic blood pressure is seen. it was noted that all members of the team had reduced systolic and diastolic blood pressure values.

Lowest recorded blood pressure values (Normal range 120 systolic 80 diastolic):

Goltis: 87 Systolic 58 Diastolic

Constantin: 63 Systolic 42 Diastolic

Andriy: 83 Systolic 52 Diastolic

Electrolyte abnormalities are gradual but progressive. Increased potassium loss can be seen quickly because of loss of visceral proteins that are rich in potassium. Potassium wasting can also occur. Negative balances for phosphorus and magnesium are likely.

Electrolyte disturbances noted in the team (limited testing ability after 7 days):

Goltis: No abnormality

Constantin: No abnormality

Andriy: (His decreased levels implies over hydration after reaching Las Palmas)

Sodium: 132.4 mmol/L (Normal range 135 - 145 mmol/L)

Chloride: 94.9 mmol/L (Normal range 100 - 110 mmol/L)

Hormonal changes include increased cortisol with decreased dexamethasone suppression and loss of the normal diurnal variation. Marked decreases in testosterone also occur. Decreased T3 and T4 are seen with decreased feedback inhibition of thyroid stimulating hormone. The decreased reaction time, easy fatigability, coordination disturbances and altered emotional control seen during starvation may be due in part to this state of mild hypothyroidism.

Endogenous vitamin stores vary widely among the fat and water soluble classes. During starvation vitamins A and B12 would not be depleted for 10 - 12 months, while vitamin C and D will be exhausted within 4 - 5 months. Of all the water soluble vitamins, thiamine has the smallest stores, with depletion possible within days and appearance of symptoms within 2 weeks. Medical studies have shown that there is marked atrophy and degeneration of all organs with starvation. The heart and the liver probably lose weight and volume in the same proportion as skeletal muscle. If a high level of metabolism is maintained signs of liver damage may appear in otherwise healthy male after 5 days of fasting.

**Creatine Kinase (CK) tested after 7 days
(Increased level implies muscle breakdown)**

Goltis: 430 iu/L (Normal range 38 - 175 iu/L)

Constantin: 538 iu/L (Normal range 38 - 175 iu/L)

Andriy: 243 iu/L (Normal range 38 - 175 iu/L)

Liver enzymes tested after 7 days:

Goltis: Normal

Constantin: Normal

Andriy: Normal

Depending on the degree of duration and nutritional deprivation and the amount of physical exertion the human body will varying decreases in speed strength, coordination and cognitive skills. Early on lethargy, irritability and reduce morale will set in. Additional early signs of headache, gastric distress, nausea, vomiting and lightheadedness may be seen. The only complaint of all of the above was abdominal pain by Constantin on day 11 and severe fatigue reported by all for the duration of the journey.

If there is a high degree of physical exertion combined with starvation, dehydration and ketosis may set in after the first day. The serum glucose can fall as low as 25mg%. A dramatic decrease in endurance would be felt within the first few days despite the preservation of lift and grip strength. The decrease in grip strength would be more insidious and parallel the loss of lean body tissue. My only measurement of how grip strength was not decreased was by arm wrestling Andriy. He beat me easily on two occasions - the first being right after he took his first sip of water in Las Palmas. The second time upon arrival in Dominican Republic I still was no match. With total fasting - motor coordination, hand speed and intellectual skills would degrade after 2 weeks. Once again I lost a chess match twice to Andriy during the voyage. At no stage I was convinced that his intellectual skills has deteriorated enough to challenge him again. Vision and hearing remained unaffected for all three team members.

The total weight loss at the end of the journey:

Goltis: 20 kg
(23% total loss)

Constantin: 12kg
(15% total loss)

Andriy: 16,5kg
(19,5% total loss)



There are many internal and external factors which played a role in the teams ability to endure the period of dehydration and starvation. Prior conditioning, determination and mental strength was the key to their successful mission. The physiologic consequences of starvation can be rapid and debilitating - I can only stand in awe on the way that the Equites team handled the physical and mental challenges during our Transatlantic sailing expedition.

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